

# ELECTRIC POWER.

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## ELECTRICAL TRANSMISSION AT NIAGARA FALLS.

BY HORATIO A. FOSTER.

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The Falls of Ni-a-ga-ra, with their tremendous and never varying flow of water, have probably provoked more discussion on the utilization of their power and the transmission of the same by electricity than all other water powers combined. Even before electrical transmission, in its present development, was dreamed of, attempts were made to take advantage of the great amount of power going to waste; and, outside of some small utilization of it for milling purposes, the canal and basin of the existing "Niagara Hydraulic Power and Manufacturing Co." has been the only serious attempt at such utilization up to the organization of the Niagara Falls Power Co. and the Cataract Construction Co.

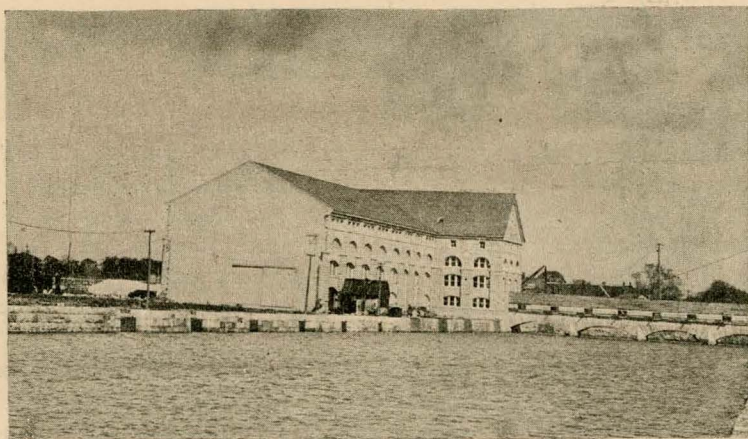
Away back in 1847, Judge Augustus Porter issued a circular calling the attention of manufacturers to the development of Niagara power, and in 1886, a prominent Rochester engineer by the name of Thomas Evershed, proposed a definite plan for developing the power from these falls, and to-day that plan has been substantially carried out, with the substitution of electrical distribution, for the lateral canals and wheel pits, then the only available method of making use of the power.

A charter for the Niagara Falls Power Co. was obtained from the Legislature on March 31, 1886, by citizens of Niagara Falls; but there being no available capital at hand, nothing was done until 1889, in June of which year the Cataract Construction Company was formed by Francis Lynde Stetson, Edward A. Wickes and William B. Rankine, all of New York City. On July 5th of the same year, having secured the necessary



capital, the Cataract Construction Company contracted with the Niagara Falls Power Company to construct all the necessary works and plant for developing and utilizing the first 100,000 H. P. of the great water power.

From the start the companies have called into their service the very best engineering talent available both from this country and Europe, and, after consulting with the most eminent hydraulic engineers and deciding on the tunnel as a tail-race and a canal above the town as a feeder from the river, an engineering Commission was appointed and a conference of the same called in London to select the best method of distribution of the power to be made available by the plans already adopted for the hydraulic part of the work.



VIEW OF POWER HOUSE, CANAL AND STONE VIADUCT FOR CONDUCTORS BETWEEN POWER HOUSE AND TRANSFORMER HOUSE.

This commission consisted of Lord Kelvin, President ; Col. Theodore Turretini, of Geneva, Switzerland ; Prof. E. Mascart, of Paris ; Dr. Coleman Sellers, of Philadelphia ; and Prof. Cawthorne Unwin, of London, who was Secretary of the Commission. It would have been next to impossible to have picked men of greater reputation and talent, and it is quite reasonable to suppose that a decision of this Commission can be taken as final.

Engineers were asked to submit plans and propositions for methods of obtaining the required results. The direct utilization of the water by means of lateral canals and wheel pits leading directly into the tailrace tunnel had to be abandoned in the beginning, owing to excessive cost of construction. The final



selection lay between distribution by compressed air and electricity, the latter eventually being chosen after the very complete report and plans submitted by Professor George Forbes, F. R. S., in 1890, in which he advocated and discussed the use of alternating currents of extremely low frequency, and to which there was, at that time, an almost unanimous opposition, but which to-day seems to be recognized as the only available method to be used for any like purpose.

Although it is the purpose of this article to deal principally with the electrical part of the works, it may not be out of place to give some data regarding the water power and other relative parts of the system.

The watershed of the Niagara or lake basin has been reliably stated as 241,235 square miles in extent, and, taken with the lake surface of 97,484 square miles, supplies a flow of water variously estimated at from 263,000 to 265,000 cubic feet per second.

This amount of water, at the total fall of 276 feet, taken from the head of the upper rapids to the whirlpool rapids, would develop some 8,250,000 horse-power, and at the actual fall utilized by the Niagara Falls Power Co. will develop something like 4,000,000 horse-power. Owing to the vast watershed and the tremendous body of water, the change in flow of water and the head and fall of the same vary so little as to be considered practically constant.

It has been estimated that about nine-tenths of all the water flows over the Canadian or Horseshoe Falls, only one-tenth flowing over the American side. Sometimes, in winter, with ice banking up at the head of the upper rapids, even less water comes to the American shore; and the writer has actually heard loud complaints from the users of water at the old Hydraulic Power Company's basin, owing to lack of water for their mills. The latter company, during the past two years, has deepened and widened its canal, and probably such complaints are not now heard.

The Niagara Falls Power Company and the Cataract Construction Company, together with the allied companies, the Niagara Development Company and the Niagara Junction Railway Company, have acquired some 1,600 acres of land in the vicinity of the river and at such points as appear to be the most available for factory sites, several miles of water front being included.

Coming, now, to the actual development of the first installment of power, we find that a short canal has been constructed at a point about a mile and a half above the American fall,



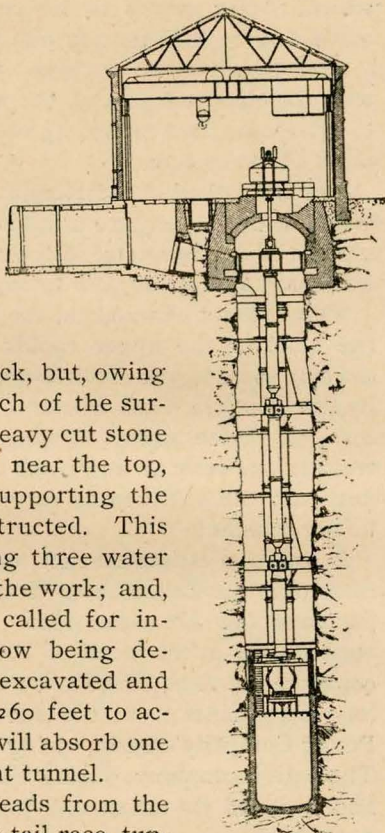
and far enough from the town to avoid any interference with the picturesqueness of that place. This canal, some 1,500 feet long by 188 feet wide and 12 feet deep, is placed somewhat diagonally with the course of the river, the inner end being the farthest up stream and directly over the present heading of the tailrace tunnel. The canal has been excavated very largely from solid rock, and the sides are built up of massive cut stone blocks, with numerous openings for outlets to wheel pits that may be constructed alongside.

At the inner end of the canal, and on its northerly side, has been dug a wheel pit 179 feet deep, 21 feet wide, and, at the present time, 140 feet long.

This wheel pit is in solid rock, but, owing to the nature of the stone, much of the surface has been lined with very heavy cut stone masonry, especially so at and near the top, where the heavy arches for supporting the dynamos have had to be constructed. This pit is capable of accommodating three water wheels of the size selected for the work; and, when the amount of power called for increases beyond the supply now being developed, the pit can be further excavated and lengthened out an additional 260 feet to accommodate ten wheels which will absorb one half the capacity of the present tunnel.

A short discharge tunnel leads from the bottom of the wheel pit to the tail race tunnel, some 6,700 feet long, which conveys the water back to the river again.

The tailrace tunnel, of horseshoe shape in cross section, is 21 feet high, 19 feet wide at the broadest part, is lined with four courses of hard brick laid in hydraulic cement, and has a total sectional area of 386 square feet. The grade or slope is from four to seven feet per 1,000 feet, and the velocity of flow of the water will be about  $26\frac{1}{2}$  feet per second, which will, it is estimated, provide for the outflow of water necessary for the development of from 100,000 to 125,000 horse power.



PENSTOCK  
AND SHAFTING.



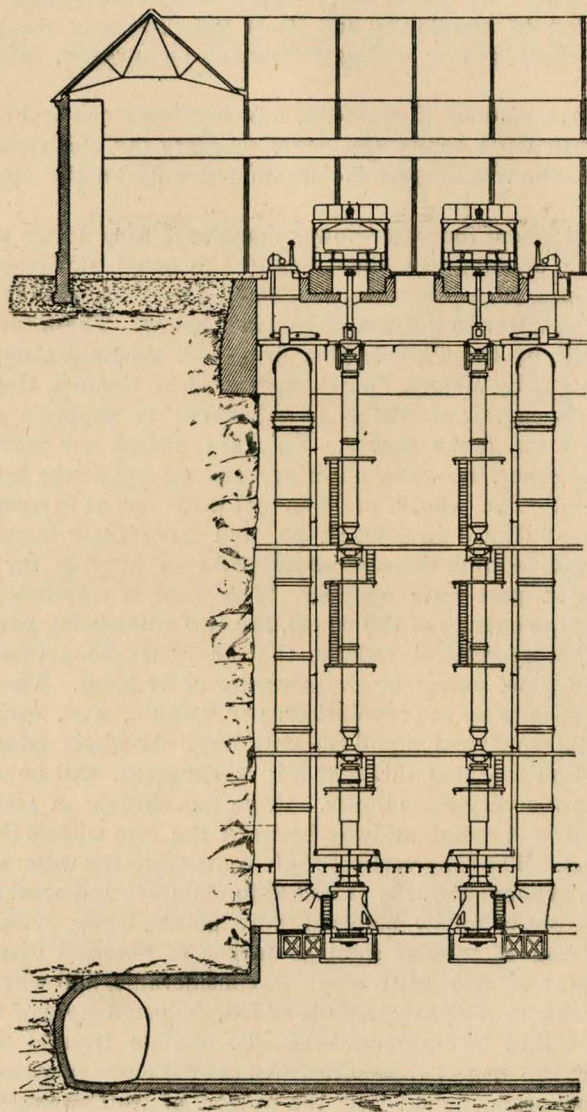
Returning again to the wheel pit ; over the top of this pit has been built a very handsome and substantial power house of cut granite, with steel frame, and a 50-ton electric travelling crane is provided to handle any and all of the extremely heavy machinery which is to be, and part of which has already, been put in place.

A massive viaduct of cut stone, supported on stone arches, has been constructed across the canal to carry the electrical conductors to the transformer house immediately on the opposite side.

A word about the water-power machinery may not be amiss. From the openings in the sides of the canal alongside the power-house, steel penstocks, seven and a half feet in diameter, convey the water to the double turbines below. These turbines were built by the Philadelphia firm, I. P. Morris & Company, after designs by Messrs. Faesch & Piccard of Geneva, Switzerland. Each pair of wheels is calculated to supply a maximum of 5,000 horse power. They are placed one vertically above the other, the water entering between and acting both up and down. The wheels are five feet three inches in diameter, are of the outward discharge type, and have their buckets or paddles divided into three separate parts to provide for high efficiency at part gate opening. The gate is a cylinder surrounding the outside of the wheel, the two gates being connected together by vertical rods, so that they may be actuated at the same time, either by the governor or by hand. The standard speed is to be 250 revolutions per minute, and, owing to the special construction and the very large fly-wheel effect demanded and obtained, this speed, it is expected, will be maintained within very close limits. From the surface of water in the canal to a point midway between the two wheels the fall is 136 feet. The long vertical shaft connecting the waterwheels with the dynamo above is 11 inches in diameter and solid at the bearings, but is hollow between those points, being cylindrical in form and of tubular steel 38 inches in external diameter. The weight of this shaft alone is considerable, and when the 40 tons weight of the dynamo is added, the usual style of thrust bearing would be impracticable. To obviate trouble of this sort, a piston surface is provided just over the upper wheel, and this is so proportioned that the weight of water pressing upwards will balance that of the shaft and other revolving parts. The cuts of the cross section of the wheel pit, as shown on pages 4 and 6 give a very clear idea of the construction of the work.

Coming now to the electrical problem ; owing to the plans of

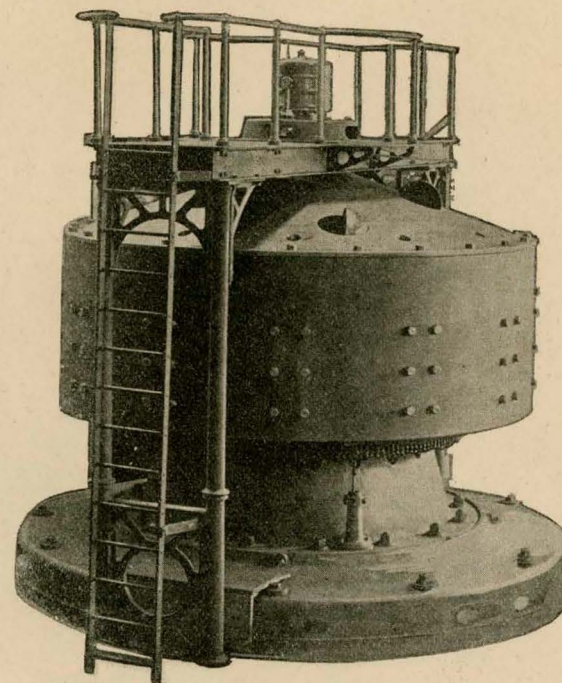




REAR VIEW OF PENSTOCKS AND SHAFTING.

the hydraulic engineers and the special construction of the wheels, the requirements of the dynamo plans were confined to very positive and narrow limits, as will be seen later on.

The three principal points in these requirements were, first, that the dynamos should be capable of developing a maximum of 5,000 electrical horse-power at their terminals; second, a fly-wheel effect of at least 1,100,000,000 pounds; third, that the revolving parts resting on the shaft should not exceed 80,000 pounds in weight.



NIAGARA DYNAMO.

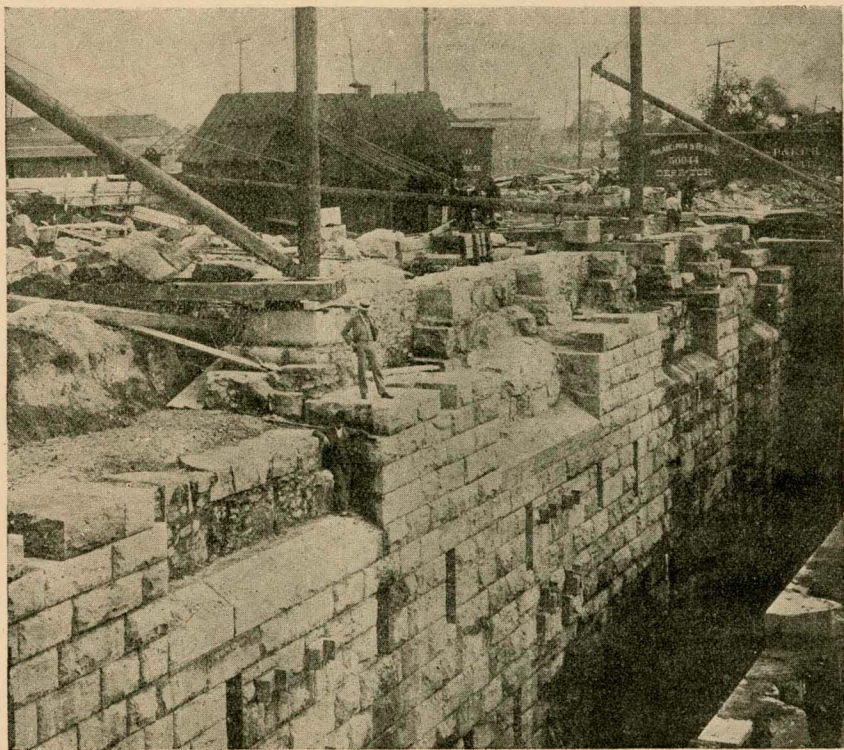
In a general way, it was necessary that the interior of the dynamo should, on the removal of certain parts, admit of the removal of the turbines or any of their connections through it; and, also, that the construction be such as to avoid all danger from the terrific centrifugal forces developed at the great speed at which the huge machine is to revolve.

Some 20 plans were submitted by different builders and designers of electrical apparatus, both in the United States and abroad, which, after careful examination by the engineers of



the company, were all rejected as not covering the requirements, and the electrical consulting engineer, Prof. George Forbes, F. R. S., was ordered by the officers of the company to design such a dynamo as would fulfill all the requirements mentioned. This he did at his London office in 1892 and 1893, and the result was slightly modified by the other engineers of the company.

The machine is an entire departure from any heretofore designed, first, in having the fields revolve outside the stationary

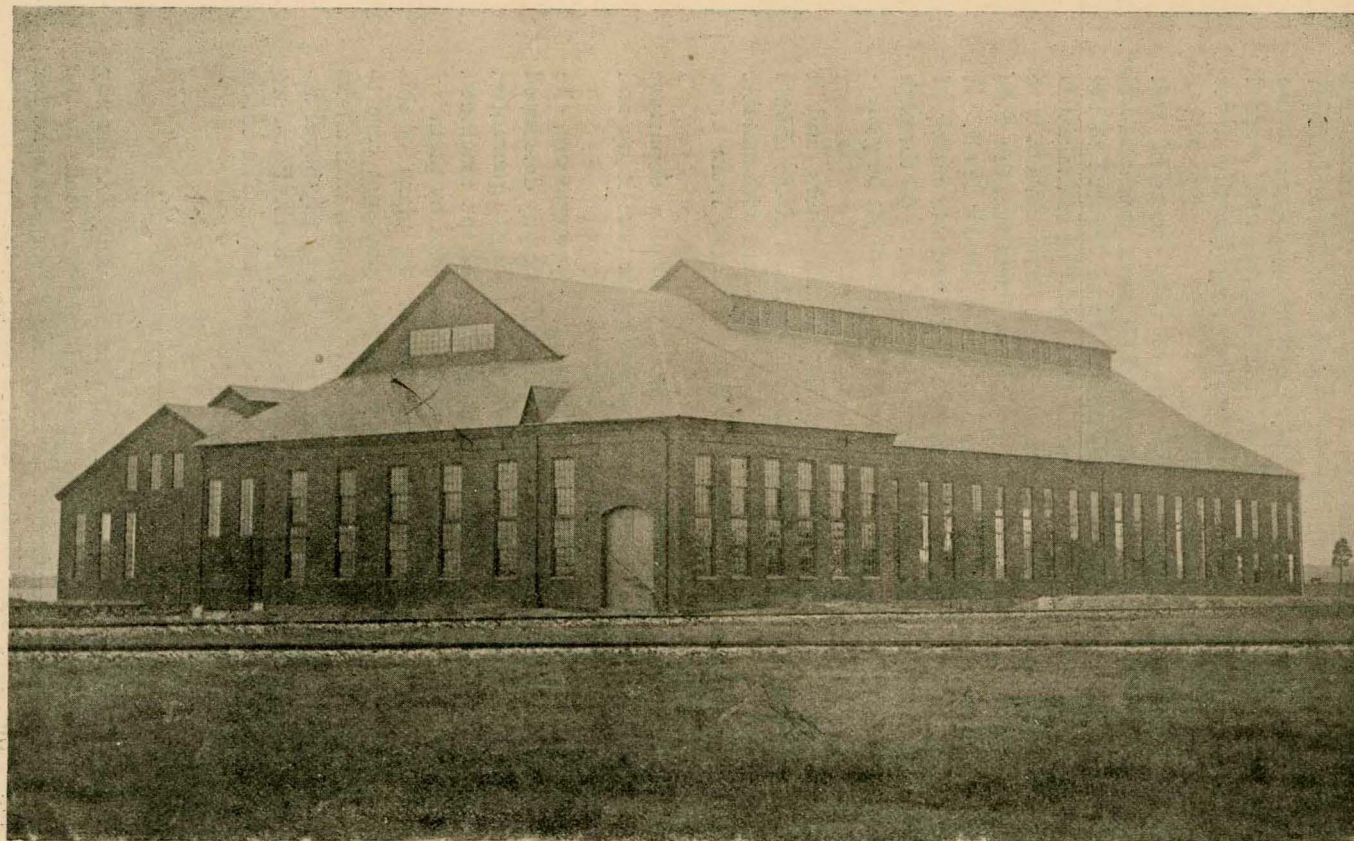


WHEEL PIT DURING CONSTRUCTION.

armature, in order to obtain the fly-wheel effect ; second, in the use of very low frequencies of a two-phase alternating current ; and, third, the novelty, for this country, of fixing the dynamo on a vertical shaft. As going to show the very narrow limits given in the requirements, it may be said that the revolving parts of this dynamo had a calculated weight of 79,940 pounds.

The field ring was to be of wrought steel, with cast steel pole





WORKS OF THE PITTSBURG REDUCTION CO., THE FIRST CUSTOMER FOR ELECTRIC POWER.



pieces and heads; the windings of strip copper, so insulated and braced as to not be in any way injured by the centrifugal force. The brushes for conveying the exciting current to the field coils were in the interior of the machine and pressed upwardly against the flat copper contact rings on the lower inner side of the carrier disc.

The armature was to be built up of thin sheets of soft iron insulated from each other by any of the usual methods, and would all be supported on a substantial frame secured to the massive foundation plate, as shown. The winding of the armature was somewhat unusual, and consisted of heavy coils of wire placed in slots around the periphery of the armature, the coils of each phase being so placed as to give the proper leads. It was proposed to enclose each coil in some suitable casing of insulating material, and then to force a circulation of oil through the coil to convey away the heat it was thought might be generated.

Each armature coil was independent of all others, and it was designed that the leads from each coil of each phase should be brought outside the machine to a point, where with suitable changing devices, any voltage could be obtained from 2,500 volts to 20,000 volts.

The dynamo as above described was so radical a departure from former practice that no one was willing to take it up and guarantee results in just the form planned.

After some discussion with the company's engineers, the Westinghouse Electric and Manufacturing Company developed a plan on similar outlines, which they were willing to guarantee, and they were awarded the contract for three of the machines. The cut on page 7 shows the dynamo as completed by them.

In another article we may be able to show the plans of this dynamo in detail, but at present the company does not care to permit them to be made public. The switch-board, with all its instruments and other attachments, will be of entirely novel design, and power will be transmitted electrically to the Pittsburg Reduction Company as soon as it can be got ready. The cut on page 9 shows these works as completed.

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Before entering a boiler that has been standing idle for any length of time, every engineer should take precautions to see that the boiler is clear of gas, or the fumes of any material the boiler may have been painted with, in laying it up.